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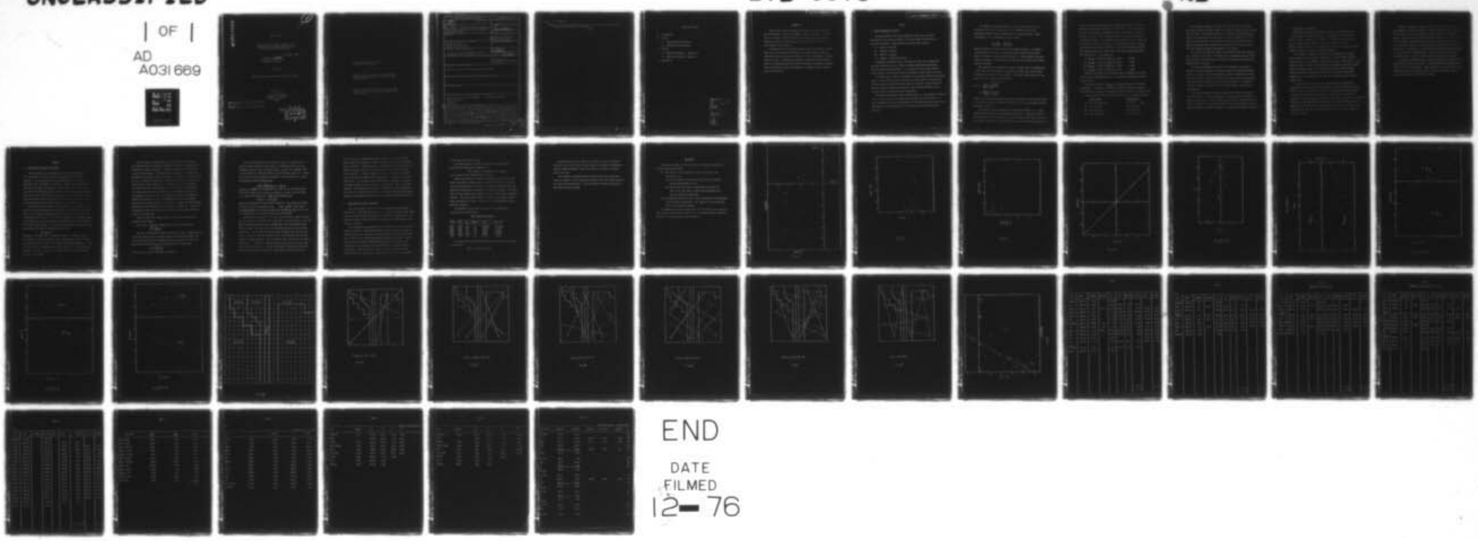

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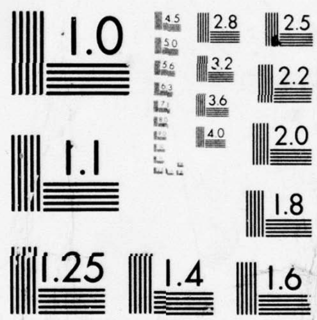

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INTERPOLATION OF GRAVITY ANOMALIES AND DEFLECTION OF THE VERTICAL COMPONENTS FROM RAPID GRAVITY SURVEY SYSTEM DATA

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July 1976

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Prepared for

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

In this report numerical tests were conducted to (1) evaluate the capability of the Rapid Geodetic Survey System (RGSS) in determining gravity anomalies and the deflection of the vertical, and (2) utilize RGSS data type in combination with other gravity data to assess the accuracy of $1^\circ \times 1^\circ$ mean anomalies for a test area. A theoretical $1^\circ \times 1^\circ$ area was developed resembling closely an actual RGSS area for which gravity anomalies were computed along n traverses. Observed gravity data were used to derive $1^\circ \times 1^\circ$ mean anomalies using the above techniques. In conclusion, the RGSS is a good instrument to be used in the measurement of → next page

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gravity; however, the RGSS did not prove to be a viable instrument in the deflection of the vertical measurements.

TABLE OF CONTENTS

INTRODUCTION

Numerical tests were conducted to (1) evaluate the capability of the Rapid Geodetic Survey System (RGSS) in determining gravity anomalies and the deflection of the vertical, and (2) utilize RGSS data type in combination with other gravity data to assess the accuracy of $1^o \times 1^o$ mean anomalies for a test area.

A theoretical $1^o \times 1^o$ area was developed resembling closely an actual RGSS area for which gravity anomalies were computed along n traverses. Observed gravity data were used to derive $1^o \times 1^o$ mean anomalies using the above techniques. Theoretical and practical computations were also conducted to interpolate Δg and vertical deflections along certain traverses. These interpolated values were computed as a function of Δg as well as Δg and elevation (h).

TASK I

a. Gravity Anomaly Prediction

The Rapid Geodetic Survey System (RGSS) has been used to provide measurements of the gravity anomaly in the White Sands, New Mexico area, along four traverses. These traverses are between the stations:

i) Carmen - WC-50 ECC

ii) Tularosa - Hanford

iii) Hanford - Tularosa

iv) Tularosa - Hanford and return.

In addition, gravimeter data is available for some of the stations in the above traverses as well as along a profile between Beasley and Huey. Since the RGSS gravity anomalies, g, are relative to the initial station of the traverse, the gravimeter data is necessary to remove this zero-offset.

To predict values of Δg, an assumption was made that transverse variations in Δg are negligible and that the dominant variation of Δg is with altitude. Although transverse effects have been explicitly ignored, they influence the results implicitly because only stations in the immediate vicinity of the station of interest were used in the predictions.

The prediction procedure used the RGSS values of g to predict the value of g at a station along the traverse where RGSS data was also available. In this way predictions could be calculated for each station along a traverse and compared with the observed value for each traverse and an rms error then computed.

Two methods of prediction were used. The first method predicted g at a station at height, h using the g and h information at the two immediately adjacent stations along the traverse and performing a linear interpolation. This interpolation can be written:

$$\frac{\Delta g - \Delta g_1}{h - h_1} = \frac{\Delta g_2 - \Delta g_1}{h_2 - h_1}$$

where the subscripts 1 and 2 refer to the adjacent stations. For example: To predict the value of Δg at station Fry, station Carmen would get subscript 1 and station White would get subscript 2. This procedure continued along the traverse. No predictions were made for the first and last stations along the traverses.

The second method of prediction involved a higher order of interpolation. In this case for each traverse, two stations on either side of the station of interest were used for the prediction. These four values of Δg and h were used to give the predicted value of Δg by

$$\Delta g = m\,h + b$$

where $m = \dfrac{4\sum \Delta g_i h_i - \sum h_i \sum \Delta g_i}{4\Sigma h_i^2 - (\Sigma h_i)^2}$

$$b = \frac{\sum h_i^2 \sum \Delta g - \sum \Delta g_i h_i \sum h_i}{4\Sigma h_i{}^2 - (\Sigma h_i)^2}$$

Hence, least square adjustments were now used to provide a linear interpolation. No values were predicted for either the first two or last two stations along a traverse in this case.

The results of these predictions are contained in Tables 1 - 4. These tables list the station and the RGSS value of Δg and h. Gravimeter values of Δg, where known, are also included. For each traverse, these gravimeter values were used to correct for the zero offset before the predictions were performed.

This was done for convenience since the RGSS data will be used later to predict the actual mean anomaly in a $1^{\circ} \times 1^{\circ}$ area. This correction was done by first plotting the RGSSΔg value vs. the gravimeter value for the four traverses. This is shown in Figure 1 where the traverses are identified by number. If the RGSS data were identical, the results would be a straight line of unit slopes passing through the origin. However, the Figure clearly reveals the offset. The relations between the RGSS and actualΔg values were found using linear least square adjustments for each traverse. The results are:

i) $\Delta g_{RGSS} = (0.978 \pm 0.014)\ g_g + 27.01 \qquad = 0.692$

ii) $\Delta g_{RGSS} = (1.022 \pm 0.025)\ g_g + 26.57 \qquad = 0.631$

iii) $\Delta g_{RGSS} = (1.048 \pm 0.017)\ g_g - 5.863 \qquad = 1.278$

iv) $\Delta g_{RGSS} = (1.068 \pm 0.026)\ g_g + 21.73 \qquad = 0.806$.

There did not appear to be a problem with instrumental drift since all the slopes are nearly equal to 1. The values of sigma are typically 1 mgal or less.

The corrected values of Δg_{RGSS} are included in Tables 1-4 and are labeled $\Delta g'$. The results of the first prediction method are under $\Delta g''$. The differences between the corrected and predicted values are also included.

The rms errors resulting from these predictions are summarized below.

	First Method	Second Method
i)	$\sigma = 13.7\ (2.7)$ mgal	$\sigma = 4.73$ mgal
ii)	$\sigma = 13.3\ (7.2)$	$\sigma = 13.1\ (7.6)$
iii)	$\sigma = 13.4\ (9.2)$	$\sigma = 13.5\ (9.0)$
iv)	$\sigma = 13.3\ (6.6)$	$\sigma = 13.0\ (8.7)$

The numbers in parentheses are the values of σ that are found when the largest differences between actual and predicted values of Δg are omitted. For the Carmen - WC50 traverse both the Fry and Bryce residuals seem anomalously large indicating a possible source of error from White since it was used in both predictions. For all three traverses between Tularosa and Hanford, the Valley Astro station has an unusually large residual and has also been dropped during the recomputation of the sigmas.

The results show that both methods can predict Δg along these traverses to an accuracy of 5-10 mgal. The higher order interpolation does not offer any advantage in accuracy though it did tend to smooth out the anomalously large residual from White.

To check for systematic variations in the residuals, the values of $\Delta g'-\Delta g''$ were plotted against the distance between the predicting stations used in method one. It had been thought that the residuals would increase with interpolating distance as transverse variations, which were explicitly ignored, became increasingly likely to affect the results. No apparent variation is seen, as shown in Figure 2, for the distance scales used in this exercise.

There does seem to be a relation between the residuals and height as shown in Figure 3. When the difference in h between predicting stations, h_2-h_1, is large there is a more likely chance to obtain a well-defined linear g vs. h relation and hence smaller residuals may be expected than where the height differences are small and a Δg vs. h relation is difficult to establish.

b. Deflection of the Vertical

The RGSS also measures the vertical deflection components ξ and η about the north and east directions. This observed data is summarized for the Carmen - WC50 traverse in Table 7. The ξ deflection component η for the remaining three traverses is contained in Table 8 and the deflection data in Table 9. These tables also contain the actual deflection components determined by astro geodetic techniques.

In an attempt to compare the observed and astrogeodetic deflection and to correct for any offsets or system bias, the RGSS values for ξ were plotted against the astrogeodetic values for the Carmen - WC50 traverse. The result is shown in Figure 5 with the data points numbered according to their order along the traverse. It is obvious that a unique relation between actual and observed deflection does not exist as it did for the gravity anomaly data. The appearance of the data is most likely due to an instrumental drift.

To better demonstrate this drift, the difference between RGSS and astrogeodetic values for ξ and η are plotted vs. distance along the traverse for the Carmen - WC50 profile in Figure 6. These differences also plotted vs. elapsed time for the three traverses between Tularosa and Hanford in Figures 7-9. In the absence of drift there should be a one to one correspondence between the actual and observed deflection values and the difference between them would remain constant (not necessarily zero) with time. However, these differences are seen to drift approximately linearly at a rate of about 10 arc sec per hour.

It might be possible to model this drift based on known instrumental characteristics and to characterize this model using least square techniques. In this way the drift will be removed and the analysis of the data could proceed. However an examination of these graphs shows that a simple linear or even parabolic curve fitting procedure alone would introduce errors of 1 to 2 arc sec (5-10 mgal). By analogy with the gravity anomaly predictions, this error is the same order as the prediction errors that might be expected by interpolating the deflection data. Hence, it would be impossible to accurately assess the errors involved in interpolating the data alone.

To summarize, the RGSS appears to suffer a serious instrumental drift in both vertical deflection components. The deflection data cannot be interpolated with this drift present. Removing the drift by simple curve fitting techniques introduces additional errors as large as the effect we wish to study, making meaningful prediction difficult.

TASK II

a. Mean Gravity Anomaly - Theoretical

The RGSS traverses are contained within an area approximately $1^\circ \times 1^\circ$ bounded by 32° 15' and 33° 15' latitude and 106° and 107° longitude. A map indicating this area, the RGSS traverses and the gravimeter data is included in this report. Before using the RGSS data to estimate the actual mean anomaly, a theoretical analysis of this area was performed to determine the best method of estimating the mean anomaly and the associated errors that may be expected. This theoretical procedure uses an increasing number of traverses to obtain an arithmetic mean which is then compared with the results obtained from a weighted mean.

This study attempted to model this situation in the following manner: the $1^\circ \times 1^\circ$ block was partitioned into 400 3' x 3' sub-blocks. The topography of the region was approximated by breaking up the elevations into 5 height classes of 4, 4.5, 5.5, 6.5 and 7.5 thousand feet and locating them on the model map in a manner roughly corresponding to the actual contours. This can be seen in Figure 10. To each of the sub-blocks a gravity anomaly was assigned whose value is related only to height:

$$\Delta g = \Delta g_0 + h.b$$

where Δg_0 = -396 mgals and b = 0.3086 mgals/meter. Furthermore, to add some realism by introducing local errors a number between -7 and +7 mgals was randomly chosen for each 3' x 3' block and added to its Δg value. Using all these values the arithmetic mean for the whole $1^\circ \times 1^\circ$ block was then computed. This will be the true mean anomaly value to which the sample means will be compared.

Given the gravity anomaly model a test was conducted to evaluate the correlation the mean anomalies calculated from samples (points along traverses) and the actual values. A set of sample values were obtained in the following manner: A "traverse set" consisting of n traverses was determined using traverse sets with values of n = 1,2,3,5,7 and 10 traverses per set. A traverse in this model is a straight line whose endpoints lie in the centers of two different 3' x 3' sub-blocks. Testing locations were then layed off at unit intervals (a unit interval is the dimension of a sub-block) along all the traverses in a set beginning with one of the endpoints of each traverse. The sub-block in which each station was located was determined and the associated Δg value for that sub-block was used as the station reading. In all cases a reading from the sub-block containing the other endpoint was included in the sample set. Figures 10 through 16 show the traverse sets used for this report (against the background of the model map).

Having obtained these sample sets, the estimated mean anomaly was computed by two methods:

(1) Taking a straight arithmetic mean of the n sample values:

$$\overset{\approx}{\overline{\Delta g}} = \frac{1}{n}\sum_{i=1}^{n} \Delta g_i$$

(2) For a few traverse sets Δg was calculated using a weighted average. First, the average of all the sample values at a given height, $\overline{\Delta g_h}$, were computed and then summed all heights with the associated weight for each $\overline{\Delta g_h}$ being the ratio of the area at that height to the total area:

$$\Delta g = \sum_{h} \frac{n_h}{400} \cdot \overline{\Delta g_h}$$

where n_h = the number of sub-blocks at height h.

If the traverse(s) did not go through an area of a certain height -- (thus no sample values for that height) -- then $\overline{\Delta g_h}$ for that height was calculated using a linear relationship where g_0 and b were computed from a least squares fit using the height -Δg pairs from the sample set. Furthermore, for the weighted average an estimate of the associated r.m.s. error was computed by the following method:

$$\delta(\widetilde{\overline{\Delta g}}) = \frac{1}{400}\sum_h \delta(\overline{\Delta g_h}) \cdot n_h + \overline{\Delta g_h} \cdot \delta n_h$$

where δn_h and $\delta(\widetilde{\Delta g_h})$ are respectively the errors in the size of the area and in the average gravity anomaly at height h. Setting n_h=1 sub-block, i.e., 1/400 of the total area. $\delta(\overline{\Delta g_h})$ was computed using:

$$\delta(\overline{\Delta g_h}) = 7 \text{ mgals}/\sqrt{N_h}$$

where N_h is the number of data points at height h. The results are listed in Table 10. μ is the population mean or $\overline{\Delta g}$. $\mu_s(\widetilde{\overline{\Delta g}})$ is the sample mean. $\Delta\mu = \mu_s - \mu$. W_s is the sample weighted mean and $\Delta W_s = W_s - \mu$. σ_{W_s} is the r.m.s. error of W_s and N is the number of values in the averages.

Certain traverse sets (1.3, 1.4, 2.2, 3.3 and 5.2) have their traverses in the right-hand valley (the White Sands area). As expected their values for $\widetilde{\overline{\Delta g}}$ are considerably off the true value $\overline{\Delta g}$ since they do not sample enough different areas. The traverses in the remaining traverse sets were chosen arbitrarily. Average values for each group of traverse sets with the same number of traverses and the associated r.m.s. error $(\bar{\mu}_s, \sigma_{\bar{\mu}_s})$ were computed without the above-mentioned 5 special traverse sets. This was to see whether $\sigma_{\bar{\mu}_s} \leq 7$ mgals. In general, a downward trend can be seen in the value of $\sigma_{\bar{\mu}_s}$ but it is not monotonic, i.e., fewer "well-chosen" traverses can sometimes lead to better values for Δg than an "unfortunate" set of more traverses.

Thus, the average is dependent not only on the number but also on the distribution of the traverses. Traverses should sample as many different areas as possible. When looking at the mean anomalies estimated using the weighted average method we see a remarkable closeness to the true value. This should not be a surprise since the model was premised on a strictly linear relationship between height and Δg and with what amounts to a small random error. So even those values of $\tilde{\overline{\Delta g}}$ based on traverses not sampling all height regions (like 1.3) are very good estimates. Thus in all cases $|\Delta W_S| < \sigma_{W_S}$. The weighted average method is preferable if Δg is postulated as essentially a function of height. This method is best used when gravity readings are abundant at various heights in a region of complex elevation.

b. <u>Mean Gravity Anomaly - Practical</u>

Only two traverses in one $1^{\circ} \times 1^{\circ}$ area had available RGSS gravity anomaly data. This data, although covering a relatively narrow height range, was used in the weighted mean technique to estimate the mean anomaly. The previous section showed the futility of arithmetic averaging using a small number of traverses.

The corrected gravity anomalies for all traverses are plotted against height in Figure 17. With the exception of three stations, Tularoas, Hanford, and Q48, a Δg-h relation can be established as shown by the straight line. There is no immediate explanation why these three stations should be so far from the trend indicated by the other twenty stations. The measurements are reproducible and the stations lie at opposite ends of the Tularosa - Hanford traverse. Perhaps there is a peculiar terrain variation present. In any case, these anomalous values were not included

in the mean anomaly calculations.

The remaining data was used in a linear regression analysis, yielding the following Δg-h relationship.

$$\Delta g = (0.446 \pm 0.015)h(m) - 584 \pm 20\,\mu g$$

The rms error of this solution was $\sigma = 8.6$ mgal.

Before the weighted mean could be computed, the $1^{o} \times 1^{o}$ area was divided into 1000 ft contour levels and the fractional area, a_i/A_i at each level estimated by overlaying the topographic map of the area with rectilinear graph paper and counting the appropriate squares. The value of Δg at these heights was extropolated from the above linear regression solution. The error at other heights is found from the above value of sigma and the error in slope. A 10% error in estimating the area was arbitrarily assumed.

The appropriate data needed to compute the weighted mean is summarized in the table below:

Mean Anomaly Data Summary

h(ft)	h(m)	Δg_i	$\delta(\Delta g_i)$	a_i/A	$\delta(a_i/A)$
8000	2438	503	30	0.00036	0.000036
7000	2134	368	25	0.0063	0.00063
6500	1981	300	22	0.066	0.0066
5500	1676	163	17	0.110	0.0110
4500	1372	27.9	13	0.278	0.0278
4000	1219	-40.3	10	0.538	0.0538

From the expression given in the previous section the mean anomaly is found to be

$$\overline{\Delta g} = 15.3 \text{ mgal} \pm 14 \text{ mgal}$$

Though the RGSS did not sample large heights and the extropolation introduces large errors in Δg at those heights, the relative contribution of these higher altitudes is small and does not overwhelm the weighted average and error.

This method of estimating the mean anomaly appears to be much more rapid and economical that saturating a particular area with random traverses to compute an arithmetic mean. A few well-chosen traverses can provide a much better weighted average.

CONCLUSIONS

Given data available for the test area the following conclusions can be drawn regarding the RGSS:

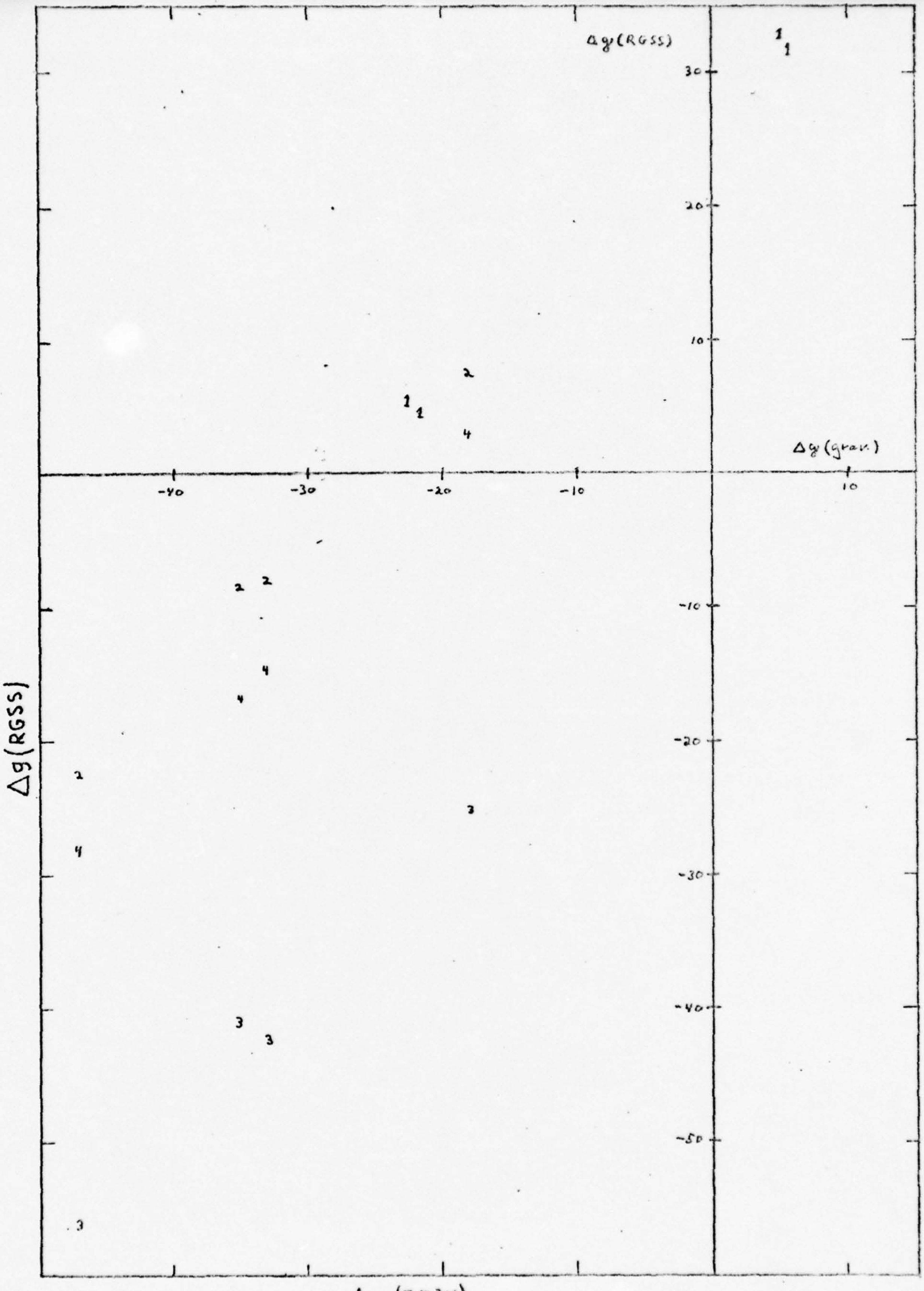
(1) The RGSS is a good instrument for use in the measurement of gravity, i.e.:

(a) The rms values of the data when compared with observed Δg was approximately $\pm$ 1 mgal.

(b) Use of RGSS data allowed interpolation of gravity in the 5 to 10 mgal range. Higher order predictions did not add significant advantages.

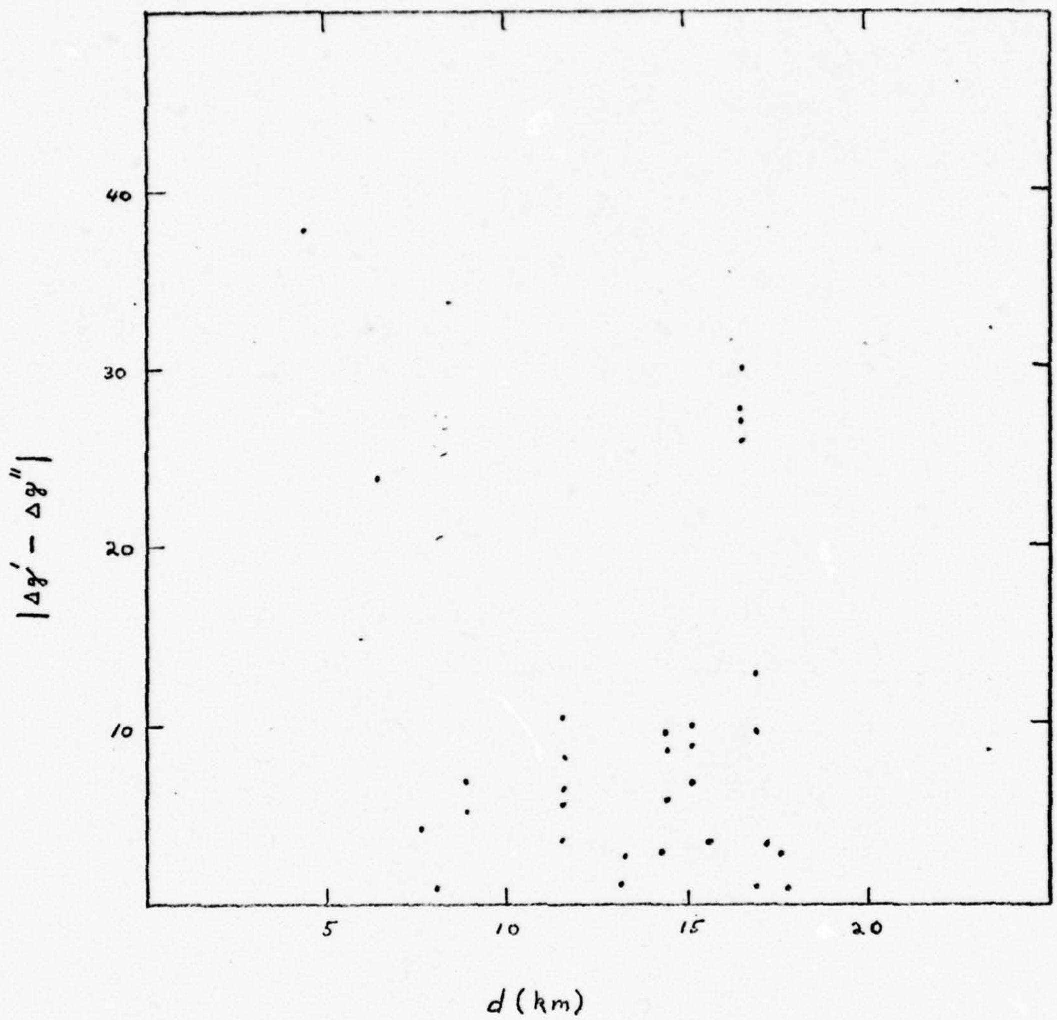
(2) The RGSS did not prove to be a viable instrument in the deflection of the vertical measurements, i.e., there was a 10 arc sec/hour drift in the available readings.

In determining the mean anomalies for a $1^{\circ} \times 1^{\circ}$ block, it was concluded that weighted mean techniques appear to be the quickest and most economical procedure in computing mean gravity anomalies.



Δg (RGSS)
Δg (grav)
Δg(RGSS)
Δg (grav.)
30
20
10
-10
-20
-30
-40
-50
-40
-30
-20
-10
10

Fig. 1



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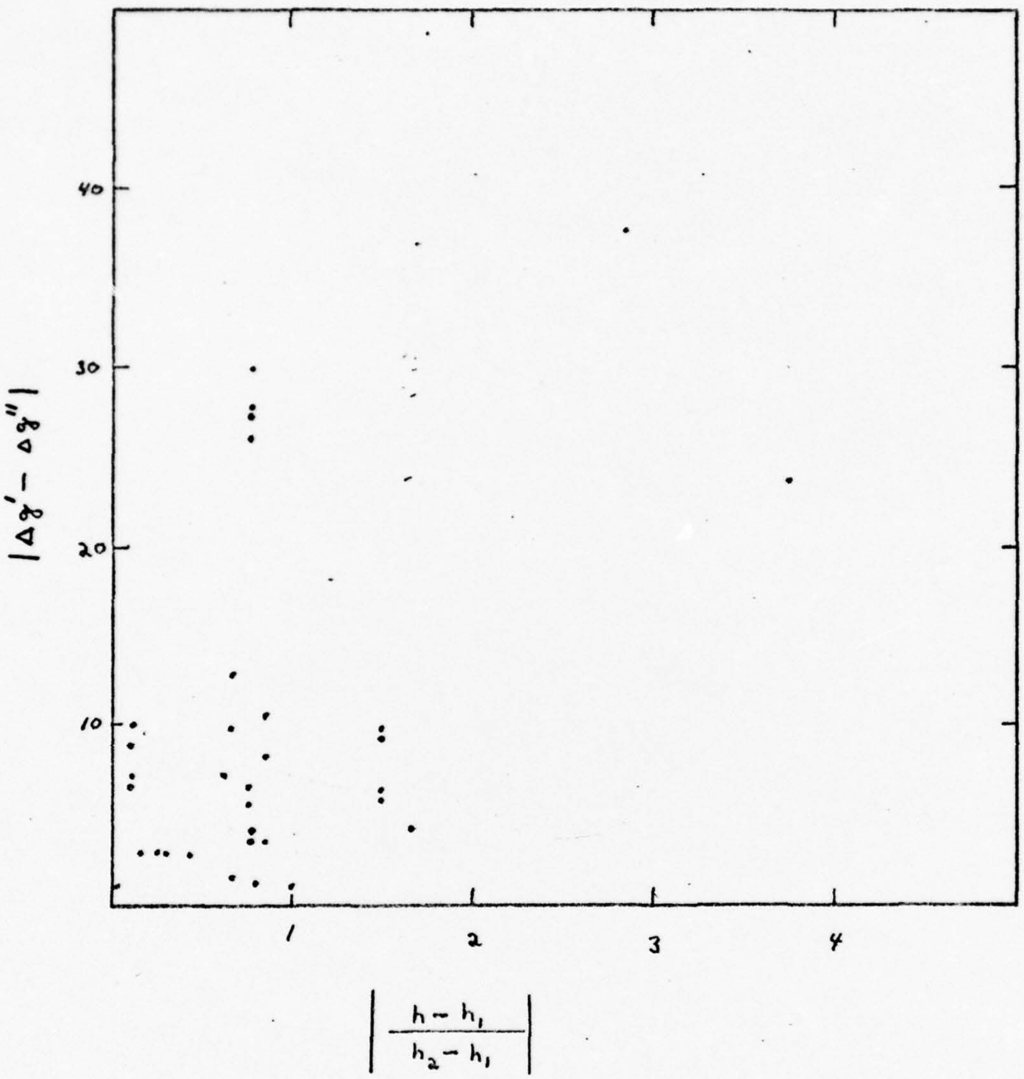

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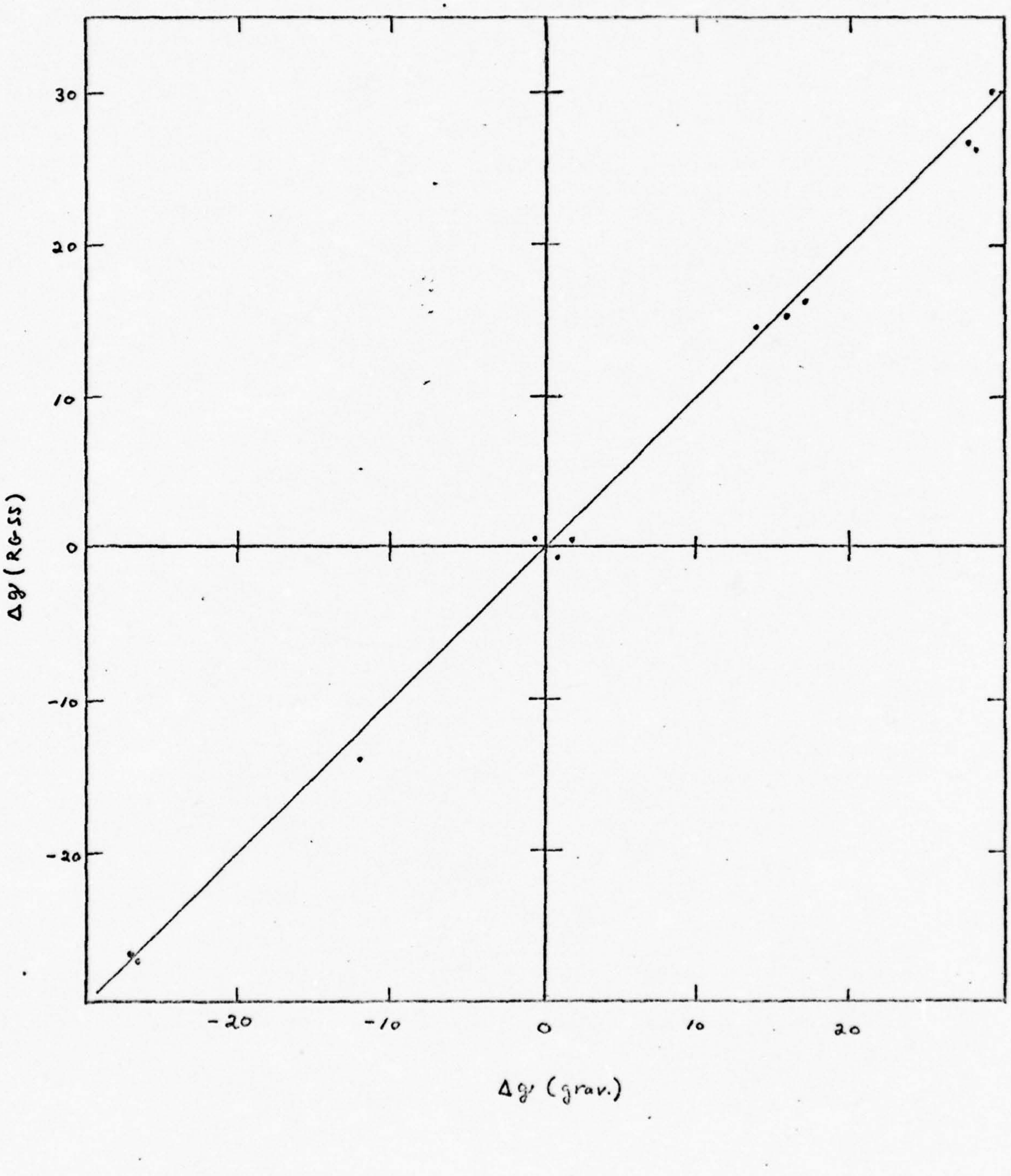
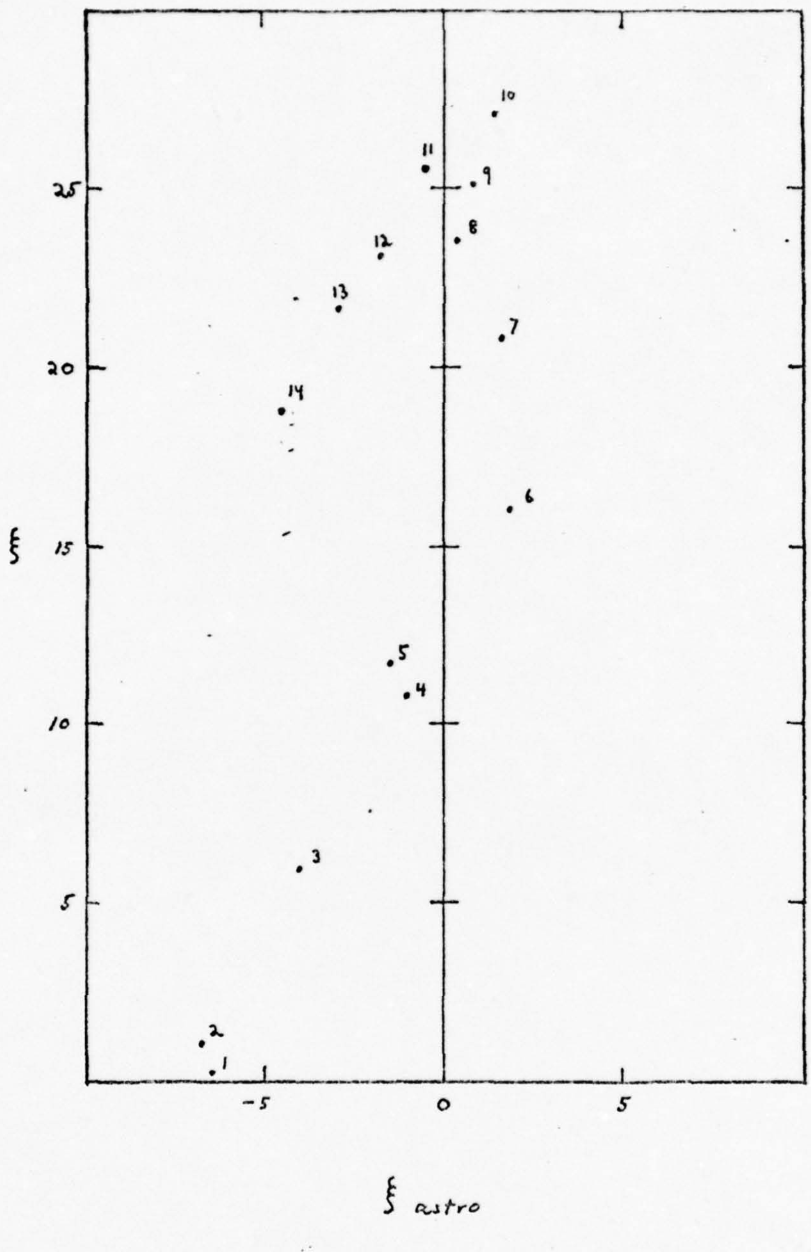


Fig. 4



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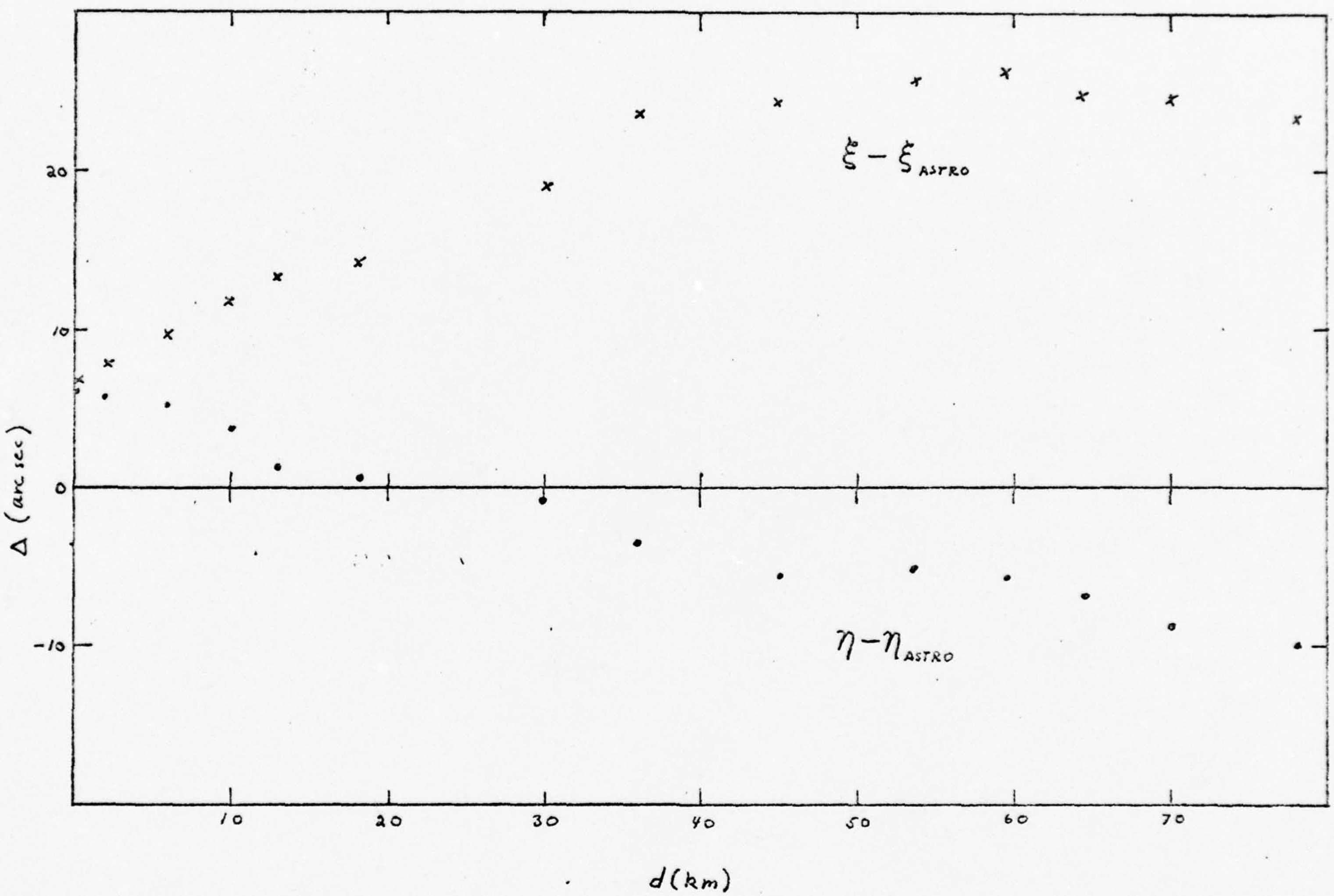
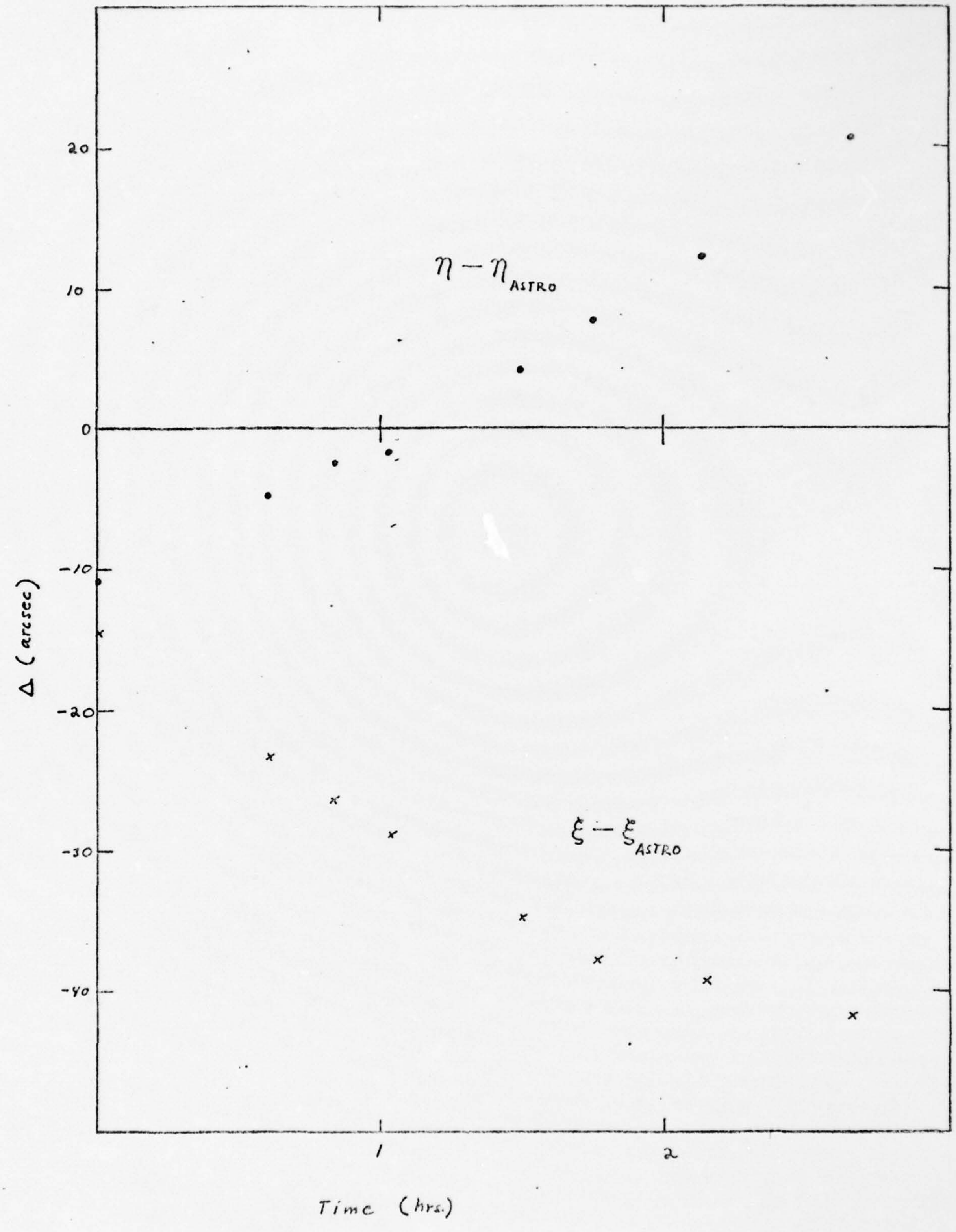


Δ (arc sec)
20
10
0
-10
10
20
30
40
50
60
70
d(km)
$\xi - \xi_{ASTRO}$
$\eta - \eta_{ASTRO}$

Fig.6 (T-1)



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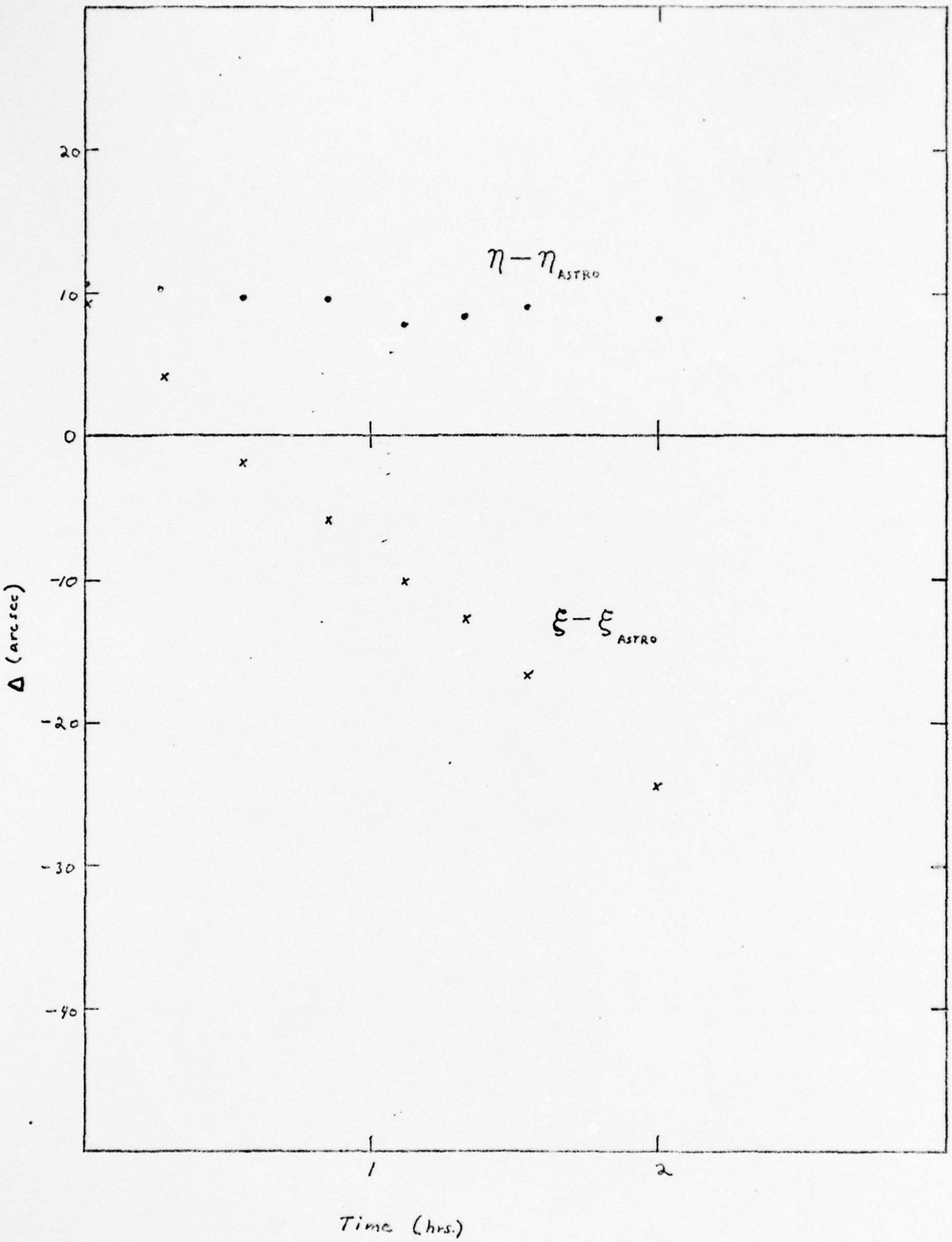

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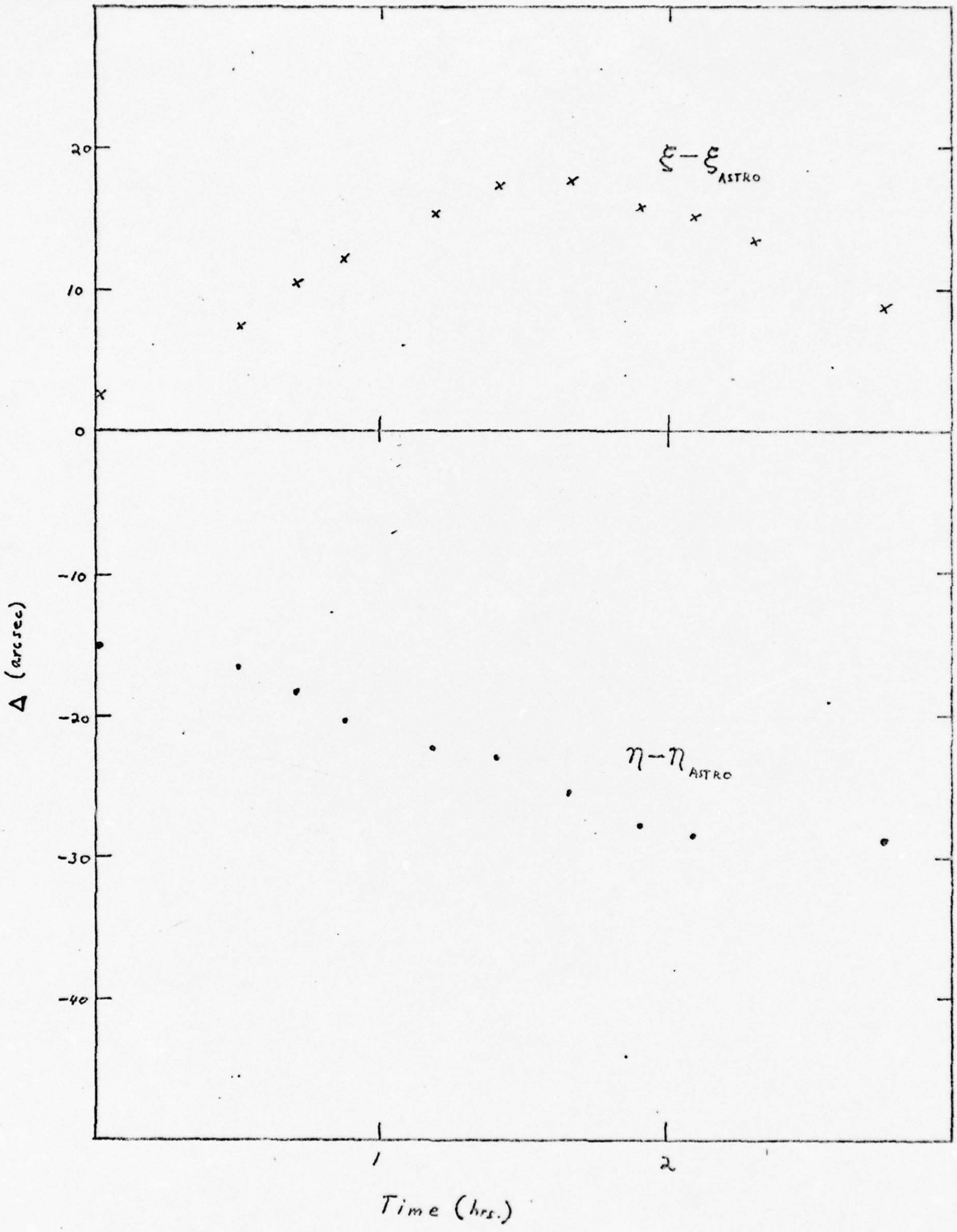

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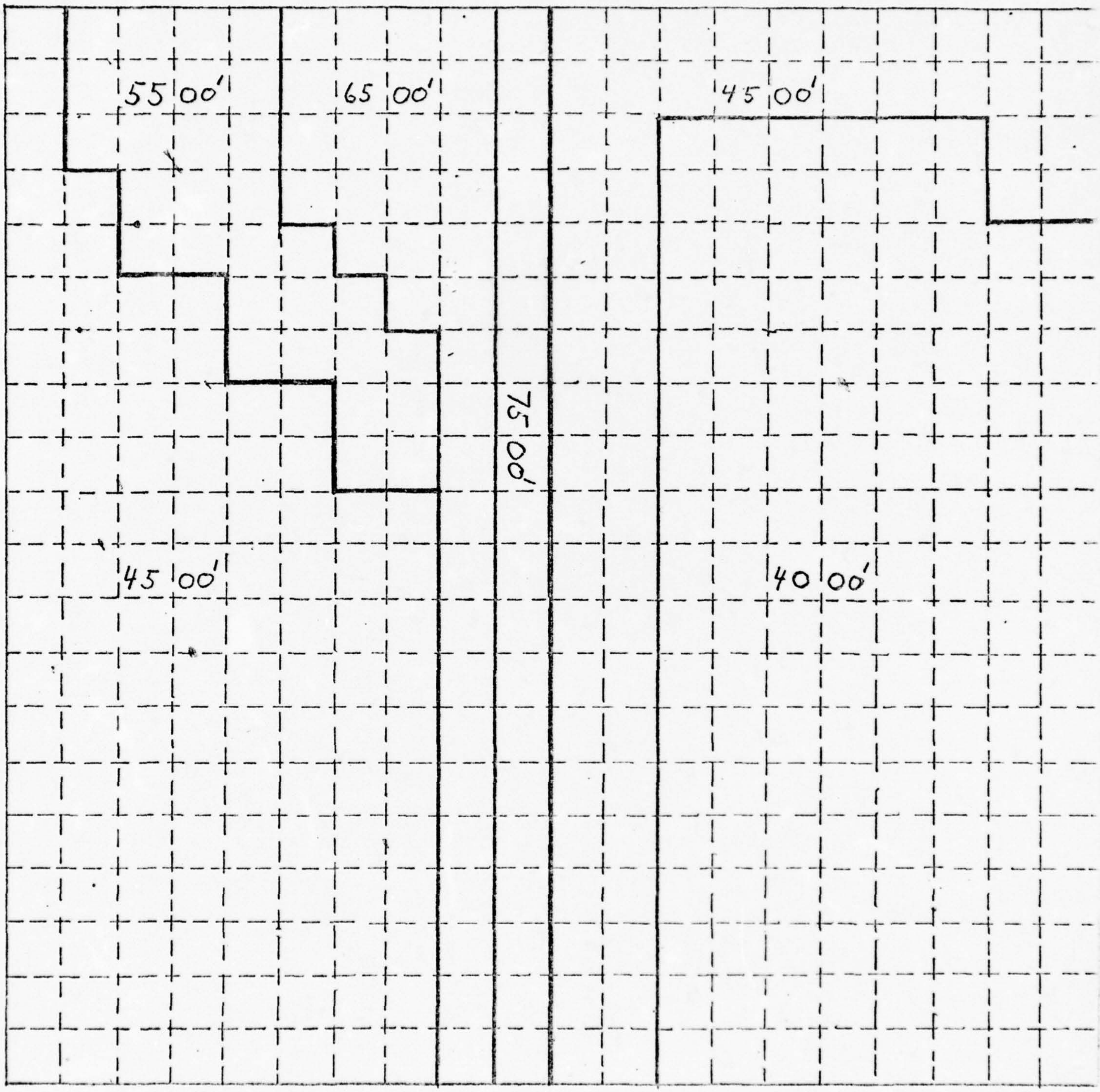
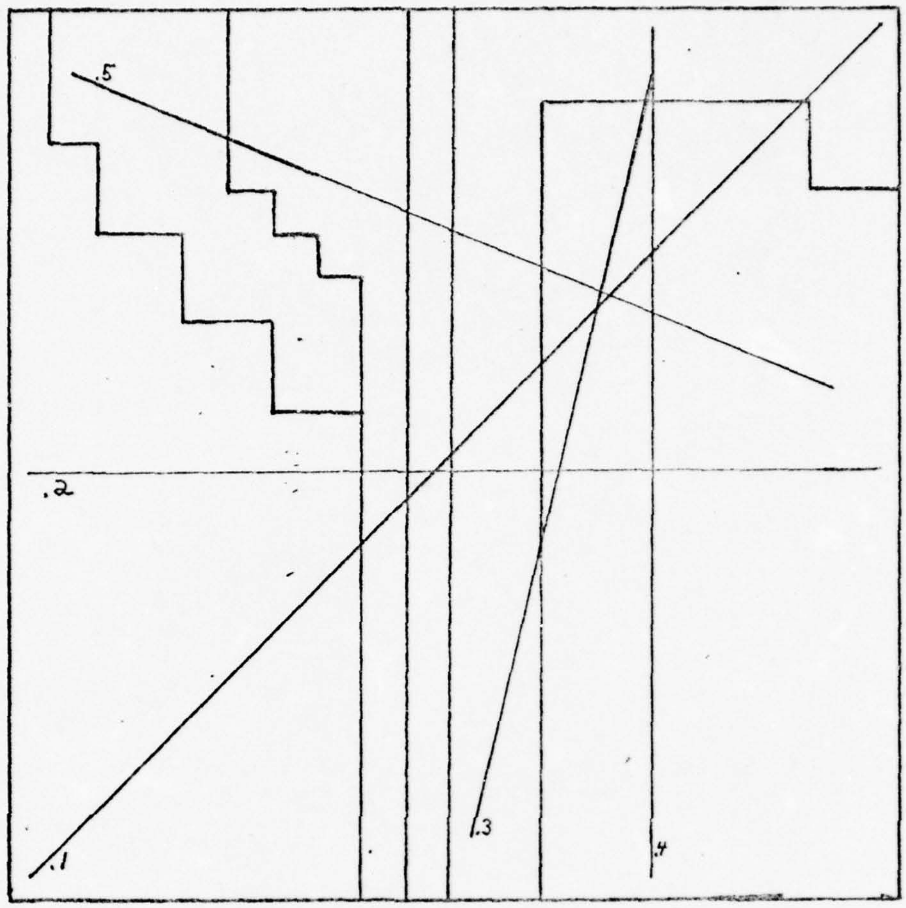
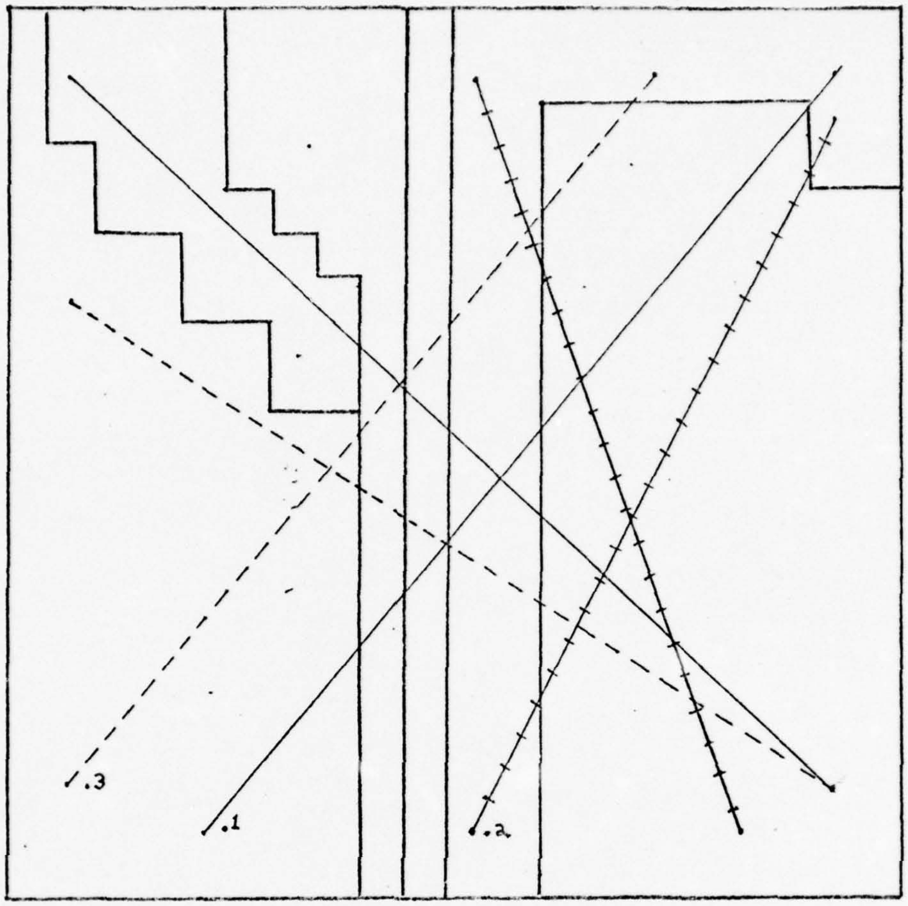


Fig. 10



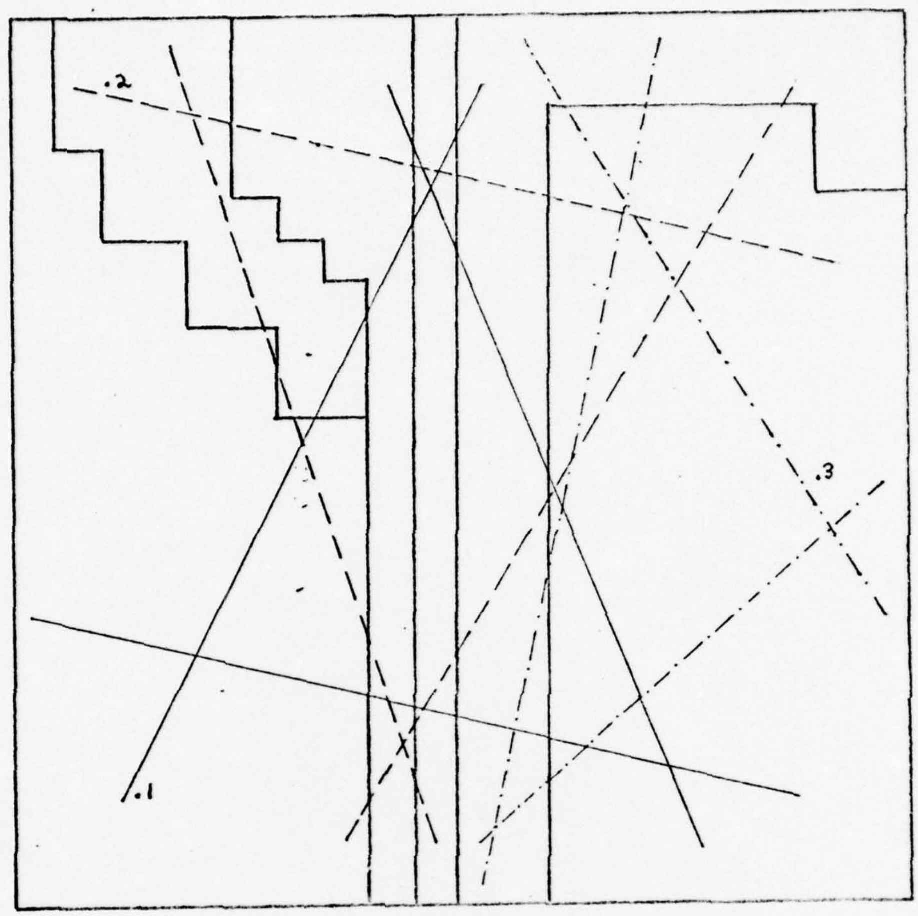
Traverses 1.1 to 1.5

Fig.11



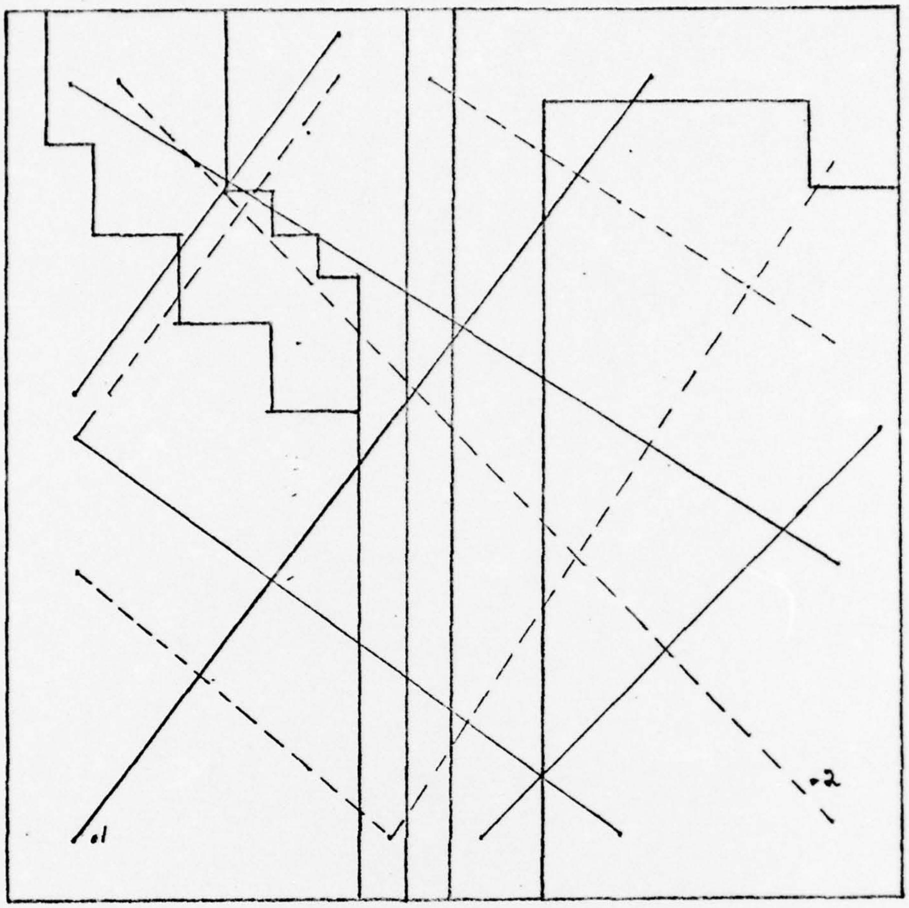
Traverse Sets 2.1–3

Fig. 12



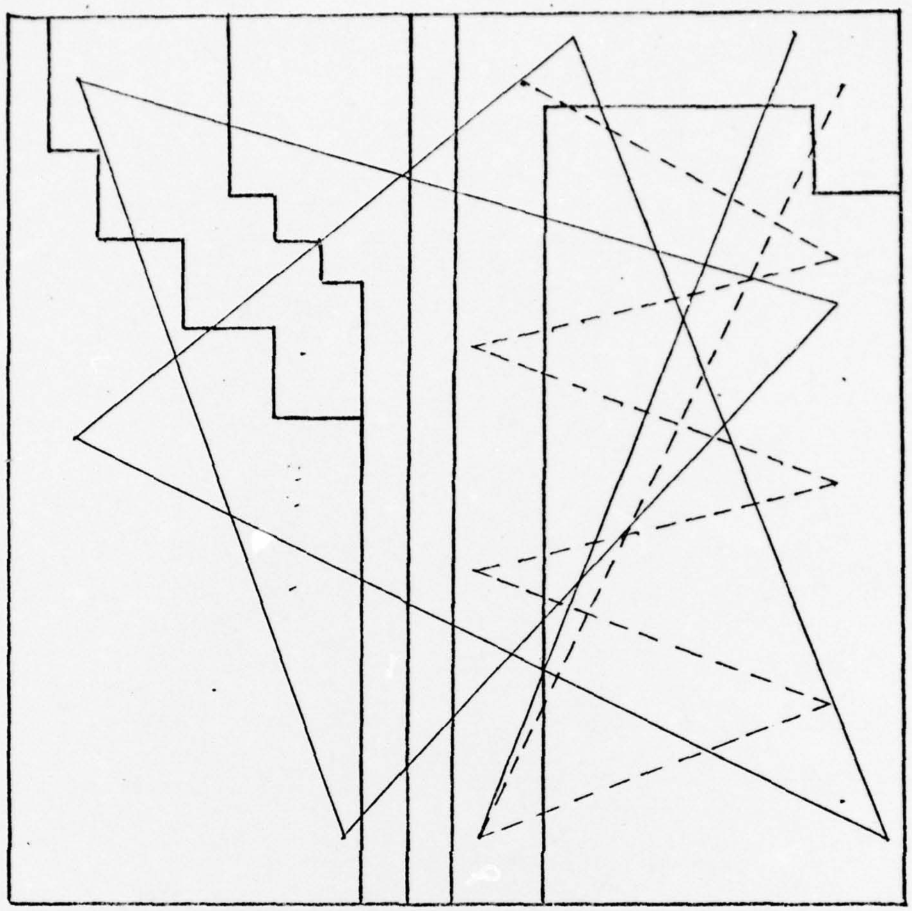
Traverse Sets 3.1–3

Fig. 13



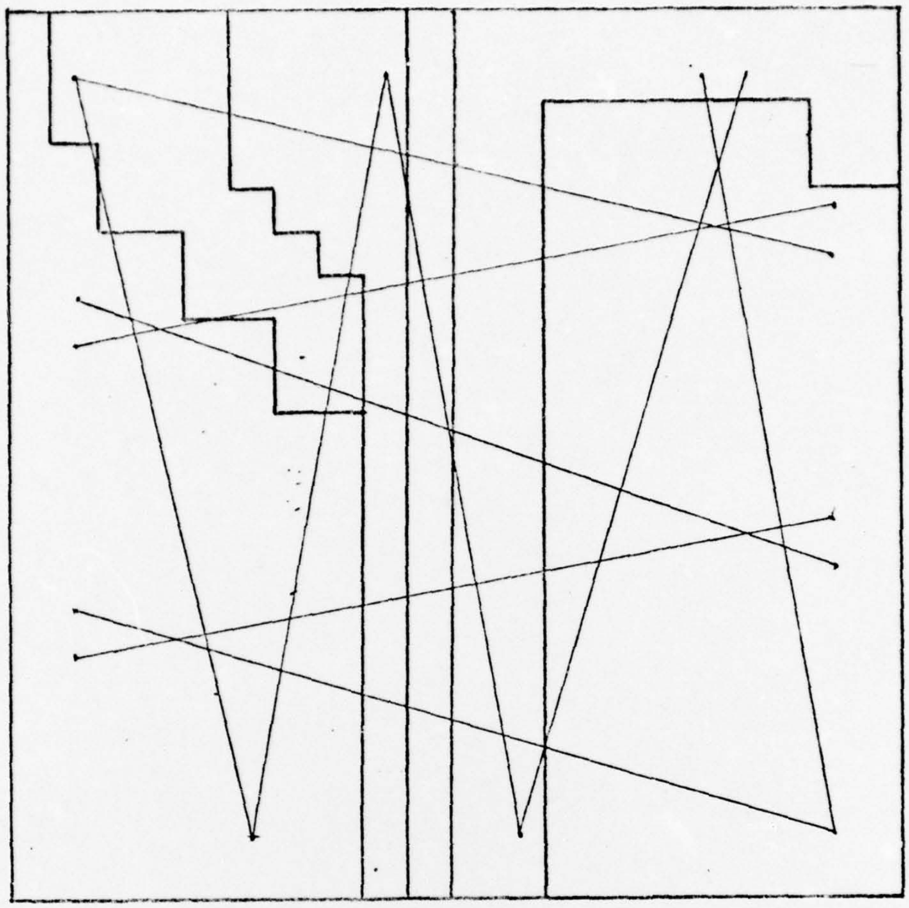
Traverse Sets 4.1-2

Fig. 14



Traverse Sets 5.1-2

Fig.15



Traverse Set 6.0

Fig. 16

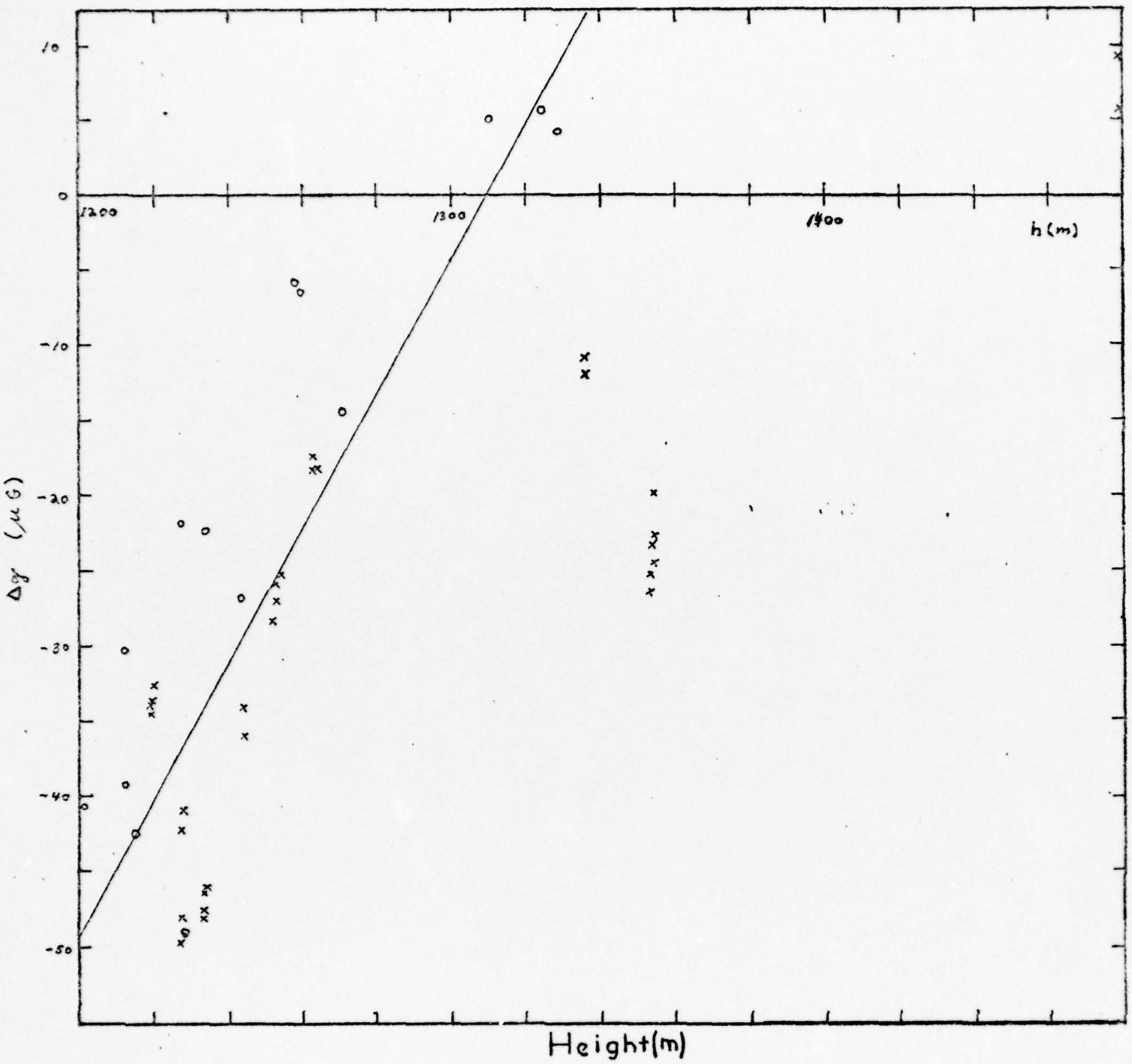


Fig.17

TABLE 1

T 1

I.D.	h(m)	Δg RGSS	Δg grav	Δg'	Δg''	D(km)	Δg'-Δg''	Δg'''	Δg'-Δg'''
Carmen	1243.65	0.76		-26.84					
Fry	1270.98	12.64		-14.69	-38.49	6.4	23.8		
White	1233.71	4.94	-21.7	-22.57	-26.84	7.6	4.27	-23.22	0.65
Bryce	1328.79	31.07		4.15	42.04	4.4	-37.89	10.17	-6.02
Nick 2	1258.30	21.28		- 5.86	- 6.89	8.0	1.03	-12.31	6.45
Geri	1259.77	20.50		- 6.66	- 5.61	18.4	- 1.05	- 5.07	-1.59
Seehorn	1324.45	32.39	4.9	5.50	8.31	17.6	- 2.81	11.38	-5.88
D-3	1310.35	31.95	5.6	5.05	1.53	15.6	3.52	3.51	1.54
NW30	1227.29	5.62	-22.7	-21.87	-24.83	17.2	2.96	-27.90	6.03
D3½	1211.88	- 2.69		-30.37	-33.02	13.2	2.65	-35.01	4.64
Shot	1201.28	-12.77		-40.67				-47.62	6.95
Gun	1212.02	-11.38		-39.25	-42.05	14.3	2.8	-39.77	0.52
Laura Center	1215.54	-14.56		-42.51	-41.34	13.2	1.17		
WC50	1228.81	-21.13		-49.22					
							σ = 13.7		σ = 4.7
							σ' = 2.70		

TABLE 2

T 2

I.D.	h(m)	Δg RGSS	Δg grav	$\Delta g'$	$\Delta g''$	D(km)	$\Delta g'-\Delta g''$	$\Delta g'''$	$\Delta g'-\Delta g'$
Tularosa	1354.89	2.6		-23.45					
Oasis	1263.23	7.8	-18.1	-18.37	-25.40	15.1	7.03		
Rhodes	1252.58	0.4		-25.61	-22.06	11.6	-3.55	-32.58	6.97
Valley Astro	1219.25	-7.8	-33.3	-33.63	-63.64	16.6	30.01	-57.60	23.97
Salt	1233.20	-22.2	-47.3	-47.72	-57.68	16.9	9.96	-37.93	- 9.79
WC50	1227.64	-22.6		-48.11	-54.24	14.4	6.14	-39.34	- 8.77
4F953	1244.79	- 8.3	-25.2	-34.12	-42.42	11.6	8.3	-42.08	7.96
Q48	1336.48	14.3		-12.01	-17.23	8.8	5.22		
Hanford	1478.99	35.8		9.03					
							σ = 13.35		σ= 13.
							σ' = 7.15		σ'= 7.

TABLE 3

Hanford to Tularosa S. B.

T 3

I.D.	h(m)	Δg RGSS	Δg grav	Δg'	Δg''	D(km)	Δg'-Δg''	Δg'''	Δg'-Δg'
Tularosa	1353.90	-33.8		-26.66					
Oasis	1262.73	-25.0	-18.1	-18.26	-28.28	15.1	10.02		
Rhodes	1252.25	-35.7		-28.47	-22.22	11.6	- 6.25	-33.29	4.8
Valley Astro	1219.33	-42.2	-33.3	-34.67	-61.96	16.6	27.29	-58.90	24.2
Salt	1233.30	-55.9	-47.3	-47.75	-60.80	16.9	13.05	-37.42	-10.3
WC50 ECC	1227.44	-58.1		-49.84	-55.70	14.4	5.86	-39.54	-10.3
4F-953	1243.99	-40.7	-35.2	-33.24	-43.91	11.6	10.67	-42.59	9.3
Q-48	1336.58	-17.1		-10.72	-17.79	8.8	7.07		
Hanford	1479.00	0.4		5.98					
							σ = 13.38		σ= 13.
							σ' = 9.20		σ'= 9.

TABLE 4

Tularosa S. B. to 4F-953 and Return

T 4

I.D.	h(m)	Δg RGSS	Δg grav	Δg'	Δg''	D(km)	Δg'-Δg''	Δg'''	Δg'-Δg'
Tularosa	1354.90	0.4		-19.97					
Oasis	1263.35	3.1	-18.1	-17.44	-26.37	15.1	8.93		
Rhodes	1253.05	- 7.2		-27.09	-21.32	11.6	5.77	-31.53	4.4
Valley Astro	1219.55	-14.5	-33.3	-33.92	-59.93	16.6	26.01	-52.82	18.9
Salt	1233.28	-27.4	-47.3	-46.47	-47.73	16.9	1.26	-35.58	-10.8
WC50-ECC	1227.93	-23.5		-42.35	-51.30	14.4	8.95		
4F-953	1244.78	-16.8	-35.2	-36.08					
WC50-ECC	1228.83	-22.1		-41.04	-50.77	14.4	9.73		
Salt	1234.52	-26.9		-45.54	-46.63	16.9	1.10	-34.34	-11.1
Valley Astro	1220.25	-13.1		-32.61	-60.33	16.6	27.72	-51.40	18.7
Rhodes	1254.02	- 5.3		-25.31	-21.46	11.6	- 3.85	-31.37	6.0
Oasis	1263.93	2.3		-18.19	-25.05	15.1	6.86		
Tularosa	1354.90	- 2.5		-22.69					
							σ = 13.35		σ= 12.
							σ' = 6.6		σ'=8.7

TABLE 5

T 0

I.D.	h(m)	Δg RGSS	Δg grav	Δg'	Δg''	Δg'-Δg''	Δg'''	Δg'-Δg'
Beasley	1204.23		-43.00					
Z 335	1204.45		-42.24		-43.05	0.81		
Y 335	1200.40		-42.19		-41.84	-0.35	-41.52	-0.67
X 335	1198.55		-41.65		-40.61	-1.04	-39.72	-1.93
W 335	1198.14		-40.26		-42.62	2.36	-41.84	1.58
V 335	1200.25		-37.62		-38.86	1.24	-39.39	1.77
U 335	1206.42		-34.77		-35.92	1.15	-36.74	1.97
Ned	1228.03		-29.96		-29.85	-0.11	-29.58	-0.38
YB 60	1233.97		-28.50		-27.44	-1.06	-27.68	-0.82
YB 59	1233.22		-27.76		-28.82	1.06	-28.32	0.56
YB 58	1241.42		-25.36		-24.85	-0.51	-24.96	-0.40
YB 57	1245.20		-23.51		-23.33	-0.18	-23.75	0.24
M 334	1245.22		-23.32		-23.50	0.18	-23.93	0.61
L 334	1240.27		-25.92		-25.01	-0.91	-24.69	-1.23
K 334	1232.81		-27.56		-26.28	-1.28	-26.31	-1.25
Fire	1228.31		-26.5		-28.08	1.58	-27.26	0.76
H 334	1219.52		-29.11		-26.65	-2.46	-28.06	-1.05
F 334	1217.06		-26.69		-30.31	3.62		
Huey	1242.71		-17.76					
						σ = 1.48		σ= 1.1

TABLE 6

Δ Stations	Δ RGSS Δ	Δ Grav Δ'	$\Delta - \Delta'$
Oasis-Valley	15.6	15.2	0.4
Oasis - Salt	30.0	29.2	-0.8
Oasis - 4F 953	16.1	17.1	-1.0
Valley - Salt	14.4	14.0	0.4
Valley - 4F 953	0.5	1.9	-1.4
Salt - 4F 953	-13.9	-12.1	-1.8
White - Seehorn	-27.45	-26.6	- .85
White - D 3	-27.01	-27.3	0.29
White - NW30	- 0.68	1.0	-1.68
Seehorn - D3	0.44	- 0.7	1.14
Seehorn - NW30	26.77	27.6	-0.83
D 3 - NW30	26.33	28.3	-1.97
			σ = 1.18

TABLE 7

T 1

Units Are Arc Seconds

I.D.	ξ	ξ Astro	η	η Astro
Carmen	0.21	-6.53	-1.44	-7.64
Fry	1.12	-6.78	-2.65	-8.37
White	5.90	-4.08	-5.14	-10.35
Bryce	10.82	-1.14	-7.14	-11.07
Nick 2	11.72	-1.40	-6.95	- 8.16
Geri	16.15	1.85	-5.77	- 6.37
Seehorn	20.84	1.67	-8.76	- 7.38
D 3	23.63	0.34	-12.43	- 8.94
NW 30	25.12	0.98	-14.03	- 8.56
D 3½	27.08	1.46	-13.24	- 8.16
Shot	25.60	-0.58	-11.79	- 6.15
Sun	23.08	-1.88	-13.80	- 6.83
Laura Center	21.68	-2.93	-13.95	- 5.08
IC 50 ECC	18.80	-4.48	-12.16	- 2.20

TABLE 8

Units Are Arc Seconds

I.D.	ξ Astro	ξ 2	ξ 3	ξ 4	ξ_4^1
Tularosa	-2.77	-17.22	-27.29	- 0.20	6.18
Oasis	--	-20.68	-20.88	3.68	10.62
Rhodes	-1.33	-24.70	-17.88	6.14	12.34
Valley Astro	-1.64	-28.06	-14.38	8.84	13.50
Salt	-1.99	-30.86	-12.06	10.08	13.88
WC 50 ECC	-4.48	-39.14	-10.12	10.72	13.06
HF 953	-5.98	-43.70	- 7.79	11.34	
Q 48	-7.47	-46.64	- 3.34		
Hanford	-9.37	-51.20	- 0.02		

TABLE 9

I.D.	η Astro	$\eta 2$	$\eta 3$	$\eta 4$	$\eta \frac{1}{4}$
Tularosa	14.97	4.46	23.24	- 0.02	-15.60
Oasis	--	1.90	18.78	- 5.22	-19.16
Rhodes	9.33	4.60	18.48	- 7.10	-19.42
Valley Astro	6.56	4.04	14.86	-11.58	-21.90
Salt	4.87	3.30	12.76	-15.46	-23.02
WC 50 ECC	- 2.20	1.98	7.36	-24.42	-27.70
4F 953	- 5.81	2.00	3.88	-28.58	
Q 48	- 8.86	3.28	1.58		
Hanford	-10.89	9.68	-0.14		

TABLE 10

Population Mean: = 79.09 mgals

Trv. Set No.	μ_s [mgals]	$\Delta\mu$ [mgal]	ω_s [mgals]	$\Delta\omega_s$ [mgal]	$\sigma\omega_s$ [mgal]	N
1.1 (1)	66.77	-12.32				28
.2	61.21	-17.88	78.70	-0.39	3.33	20
[.3]	27.94	-51.16	77.62	-1.47	3.35	18
[.4]	10.32	-68.77				20
.5	115.97	36.87	81.03	1.94	3.96	19
$\bar{\mu}_s, \sigma_{\bar{\mu}_s}$	81.32	24.70				
2.1 (2)	87.03	7.93				47
[.2]	19.91	-59.18				38
.3	75.84	- 3.25				42
$\bar{\mu}_s, \sigma_{\bar{\mu}_s}$	81.44	6.06				
3.1 (3)	104.94	25.85				57
.2	118.36	39.26	79.68	0.59	1.89	59
[.3]	20.78	-58.32				49
$\bar{\mu}_s, \sigma_{\bar{\mu}_s}$	111.65	33.24				
4.1 (5)	89.21	10.11				84
.2	86.94	7.85				76
$\bar{\mu}_s, \sigma_{\bar{\mu}_s}$	88.08	9.05				
5.1 (7)	68.57	-10.53				131
[.2]	18.31	-60.78				77
6.1 (10)	83.10	4.01				183